Airborne Measurements of Snow Cover Properties During the Cold Land Processes Experiments Using the Polarimetric Scanning Radiometer (PSR)

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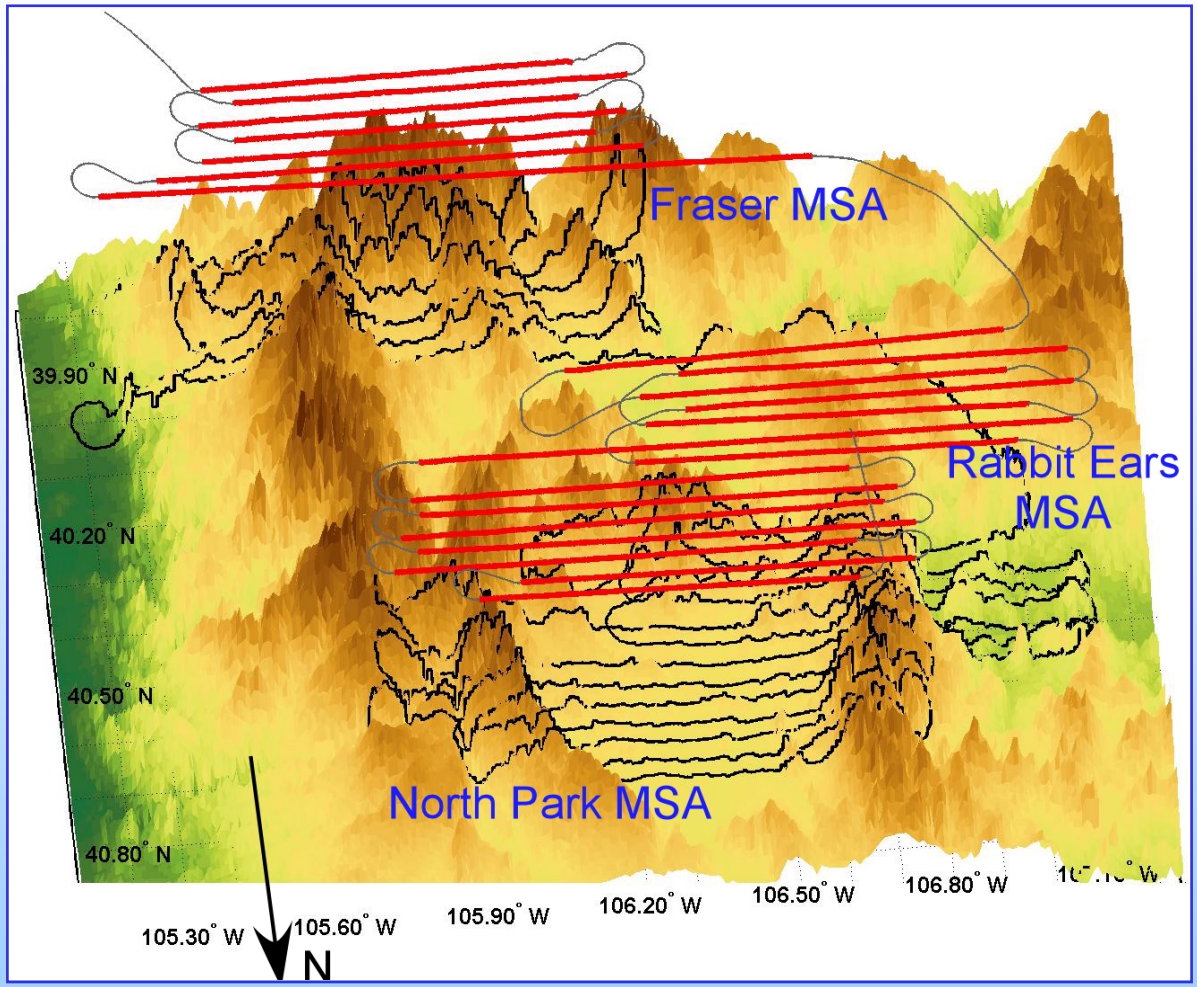
Introduction

During Cold Land Processes Experiments (CLPX) in February 2002 and 2003, and March 2003, multispectral polarimetric microwave brightness temperature maps of snowpack in the Colorado Rocky Mountains were obtained using the NOAA Polarimetric Scanning Radiometer (PSR). These data are being used for several purposes including:

- calibration and validation of the AMSR-E sensor
- snowpack and snowmelt hydrology
- cryospheric satellite sensor design
- snow emissivity modeling
- snowpack change detection

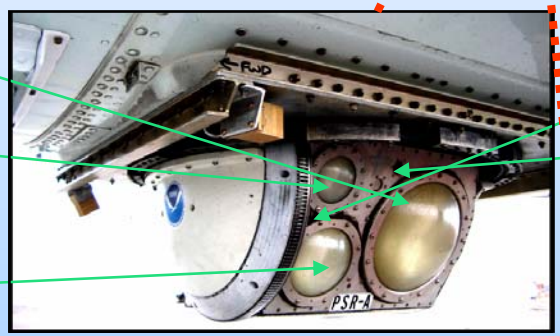
CLPX PSR Experimental Area



3D view of the CLPX Mesoscale Study Areas (MSA) that were sampled during February 2002, February 2003 and March 2003. Flight lines (red), flight lines projection onto the ground (black)

CLPX PSR Configuration

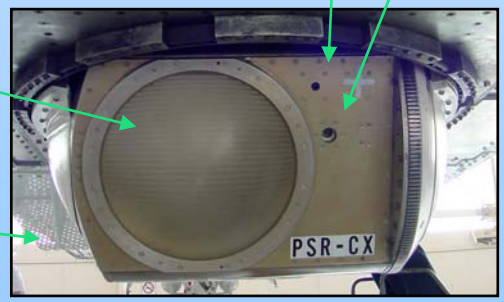
	CLPX02	CLPX03A	CLPX03B
Aircraft	DC8	P-3	P-3
Scanhead	PSR/A	PSR/A	PSR/A PSR/CX



10.7 GHz
37.0 GHz
89.0 GHz
18.7 GHz
21.5 GHz

Video

10 μm IR



6.7 GHz
10.7 GHz

Aerodynamic Fence

PSR Radiometer System Parameters

- PSR is the first operational airborne multi-band conically-scanning imaging radiometer.
- The PSR was designed for a variety of high-resolution environmental remote sensing purposes and it is uniquely suited for CLPX studies.
- The most recent PSR hardware improvement permits simultaneous use of multiple PSR scanheads on a single aircraft to provide imagery at all of the AMSR-E bands.

Frequency (GHz)	Scanhead	Polarization	Beamwidth[1] (°)	ΔT_{rms}[2] (K)
5.8-7.5	PSR/CX[3]	v,h,U,V	10	0.2
10.6-10.8	PSR/CX[3] PSR/A	v,h,U,V	7 8	0.4 0.6
18.6-18.8	PSR/A	v,h,U,V	8	0.3
21.4-21.7 (H_2O)	PSR/A	v,h	8	0.4
36-38	PSR/A	v,h,U,V	2.3	0.5
86-92	PSR/A	v,h,U	2.3	0.6
10 µm (IR)	PSR/A	unpolarized	7	0.2

[1] Half-power beamwidth; [2] 18 msec equivalent integration time, v & h; [3] Multiple Sub-bands for interference mitigation

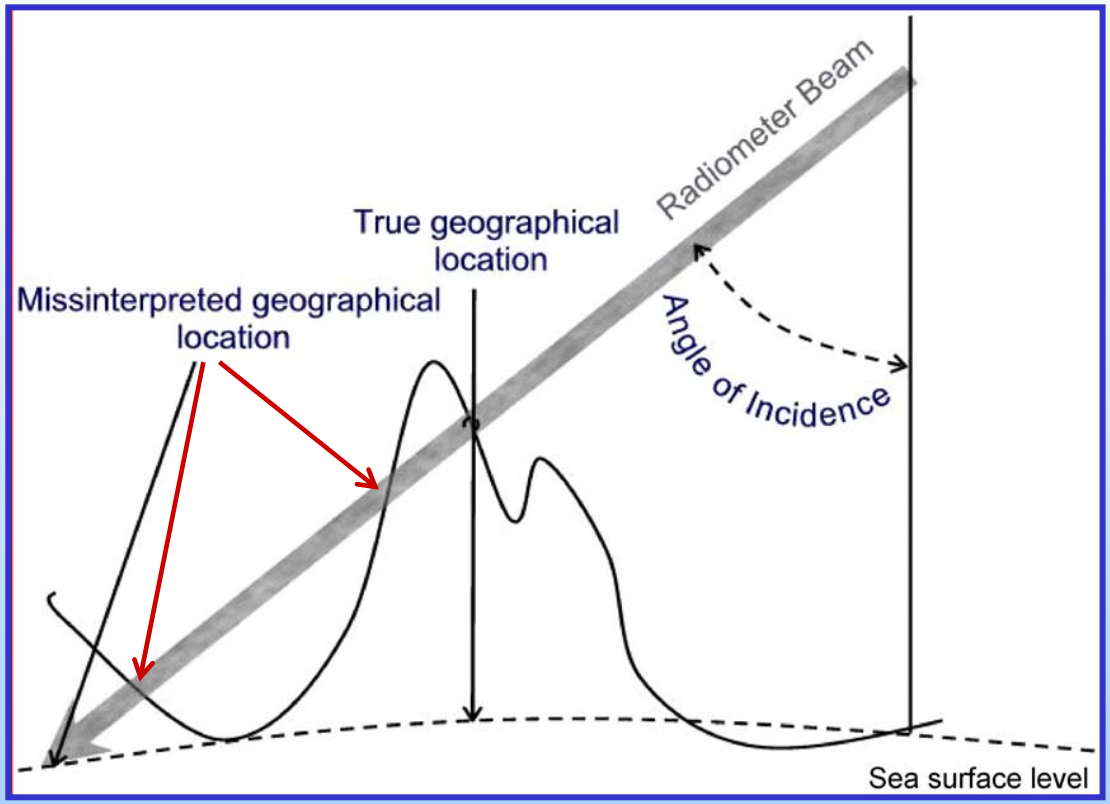
CLPX PSR Data Summary

Exp. Name	MSA	Date	Obs. Times (UTC)	Tot. # of Flt. Lines	Flt. Alt. (km AGL)	3 dB Spatial Resolution Range (m) @ 37, 89 / 10, 18, 21 GHz
CLPX02	RE	2/19/02	21:18-22:35	7	2.34	88 / 308 – 209/728
	FM	2/21/02	16:45-18:49	7	2.10	55 / 191 – 234/812
	NP	2/23/02	16:57-18:34	7	2.10	54/ 184 – 203/708
CLPX03A	NP	2/22/03	18:35-20:35	7	3.93	184 / 642 – 334/1161
	NP, RE, FM	2/23/03	17:35-21:37	21	2.18	65 / 229 – 215/749
	NP, RE	2/24/03	20:30-23:05	14	2.22	71 / 246 – 206/718
	NP, RE, FM	2/25/03	17:30-21:00	21	2.18	65 / 229 – 215/749
CLPX03B	NP, RE, FM	3/25/03	17:50-22:05	21	2.18	65 / 229 – 215/749
	NP, RE, FM	3/30/03	18:10-22:30	21	2.18	65 / 229 – 215/749
	NP, RE, FM	3/31/03	17:50-21:50	21	2.18	65 / 229 – 215/749

Principal Investigator: Don Cline
PSR Team: A.J. Gasiewski, B.B. Stankov, B.L. Weber
Quicklook data can be found at http://www.etl.noaa.gov/data/psr/clpx03/

Total flight hours = 29.7
# of flight lines = 147

CLPX Spot Geolocation



- CLPX mountainous areas required a ray-tracing geolocation procedure.
- This procedure used USGS 30-m resolution terrain data to locate points where PSR beams intersected the surface.

CLPX03 PSR/A Snowpack Images

PSR data obtained during CLPX has provided unique insights into snowpack spatial and temporal variation and microwave polarization and spectral behavior.

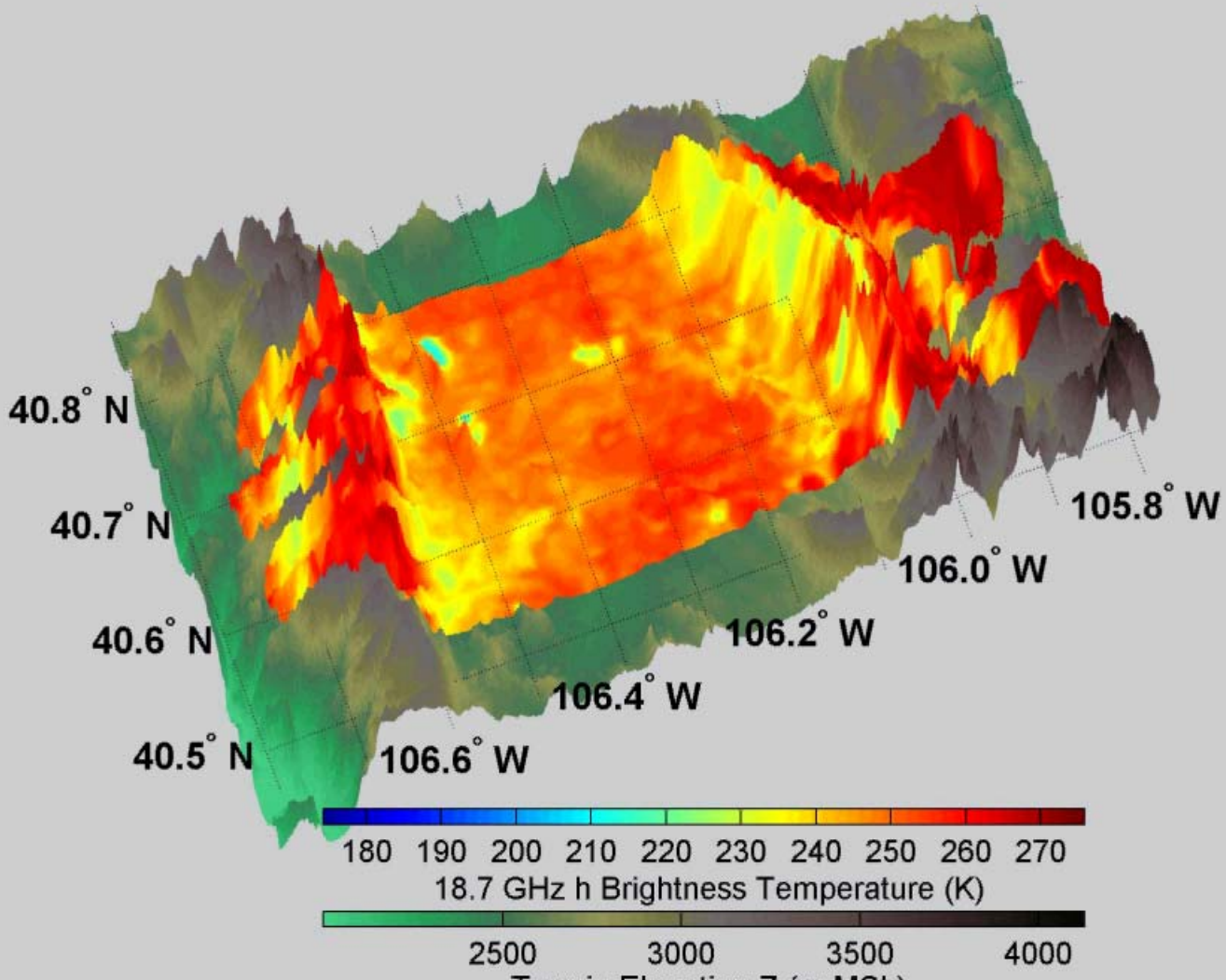
As an example of spectral behavior next two slides show time sequence of 18 and 37 GHz horizontally polarized brightness temperature maps for North Park area starting in February 2002 and continuing through February and March 2003.

Points to note are:

- Brightness temperature drop from February 2002 to February 2003 suggesting widespread snow coverage in 2003.
- Onset of snowmelt with an opposite brightness temperature trends between February and March 2003.

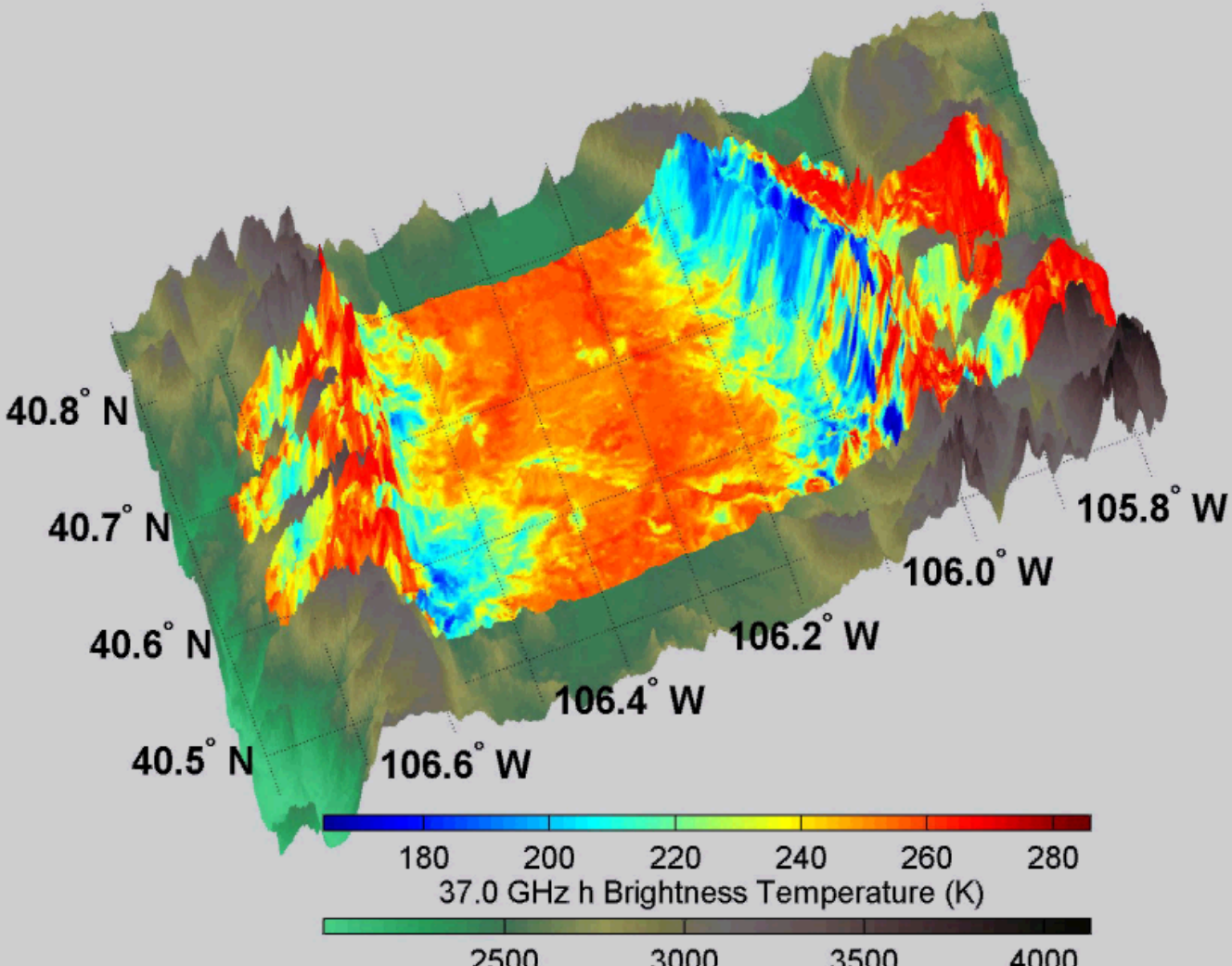
CLPX02

NorthPark: CLPX02 02/23/2002 18.7 GHz Th



CLPX02

NorthPark: CLPX02 02/23/2002 37.0 GHz Th



Snow Water Equivalent Estimation

Scattering from ice particles decreases observed brightness temperatures (T_B) for higher frequency channels relative to a lower frequency T_B measurements. This concept has been historically used to estimate the snow water equivalent (SWE):

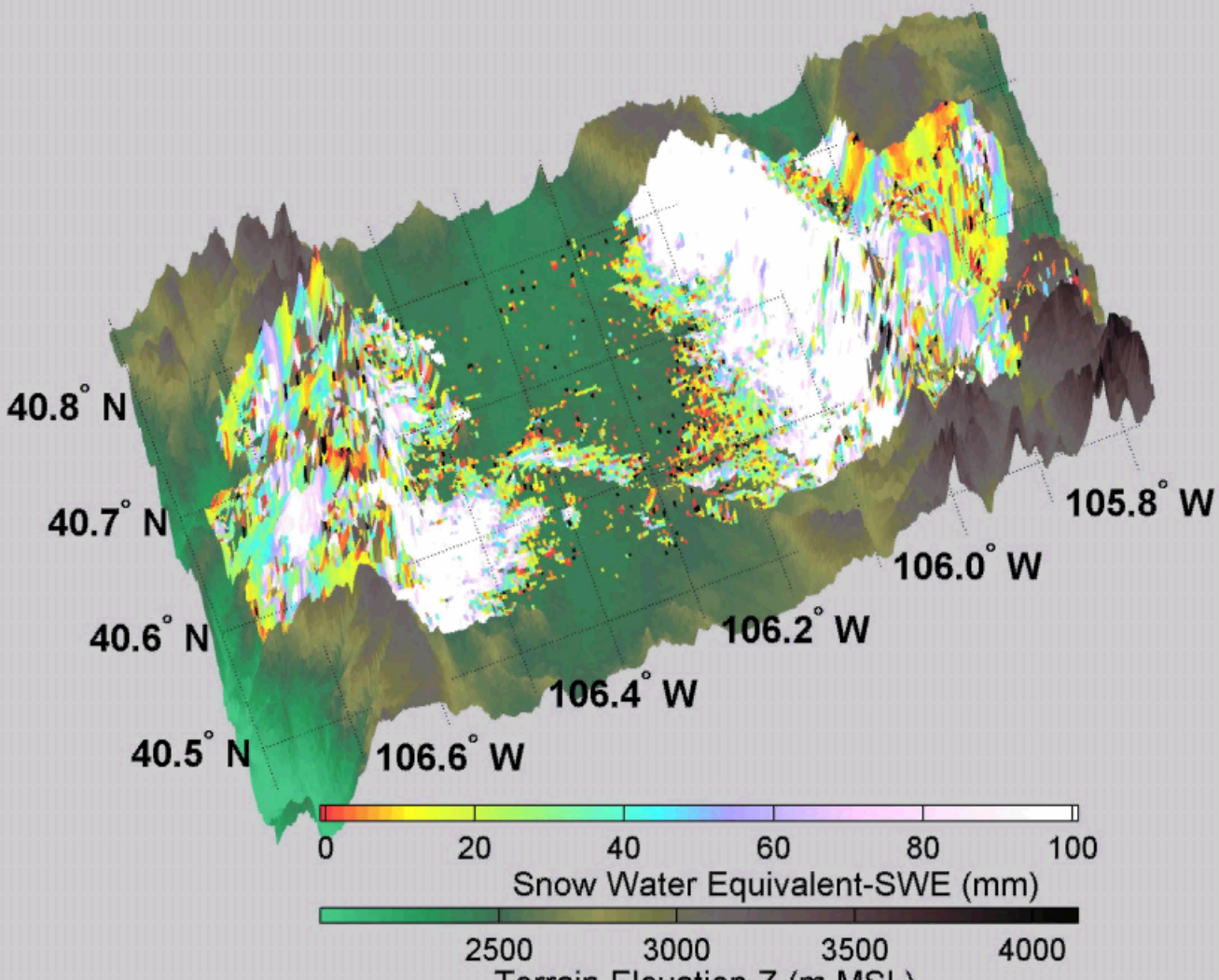
$$SWE = 4.8 * (T_{B18.7H} - T_{B37H}) \quad (mm)$$

***where a* = 4.8 mm K^{-1}** for: snow grain radius of 0.3 mm
snow density of 300 kg m^{-3}

Chang, A.T. C., J.L. Foster and D.K. Hall, 1987: "Nimbus-7 derived global snow cover parameters," Annals of Glaciology, vol. 9, pp. 39-44.

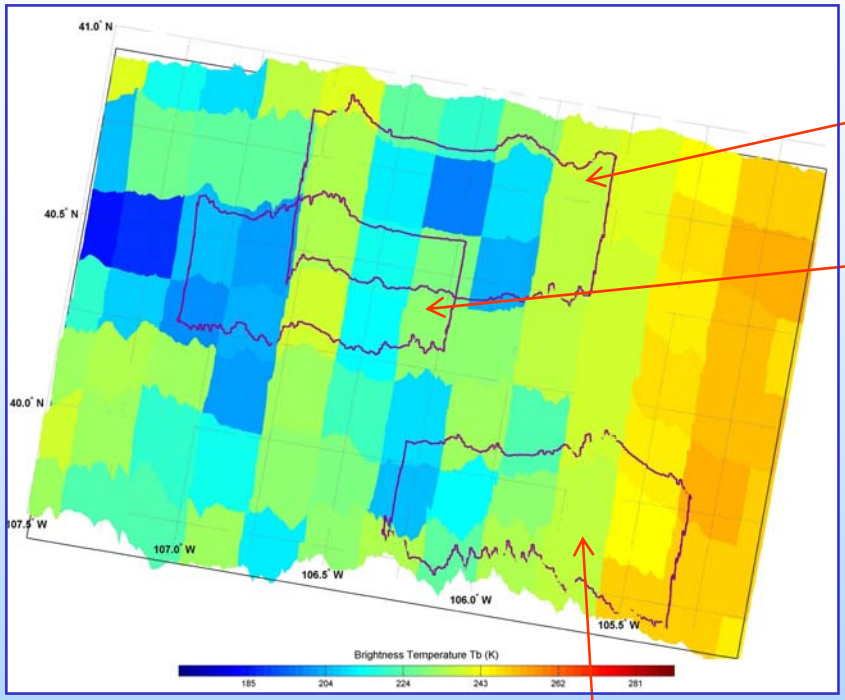
CLPX02

NorthPark: CLPX02 02/23/2002



AMSR-E 37 GHz H-Pol T_B Imagery

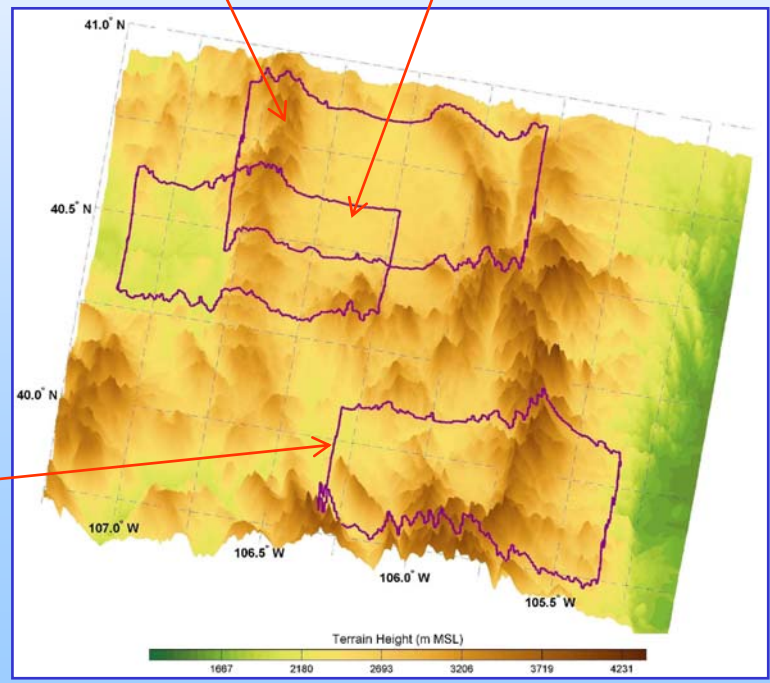
- February 23, 2003 CLPX03A -



North Park

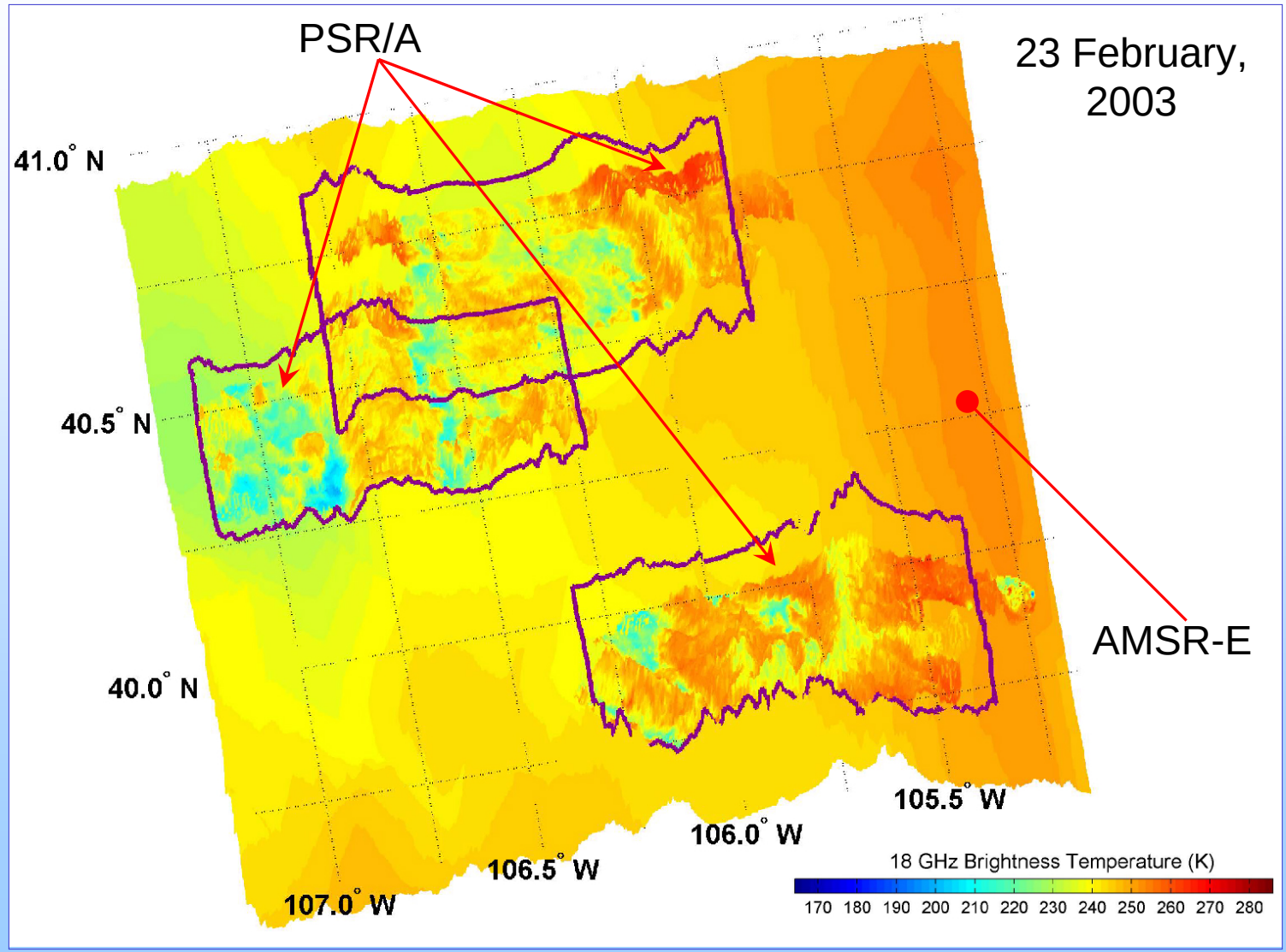
Rabbit Ears

Fraser Meadows



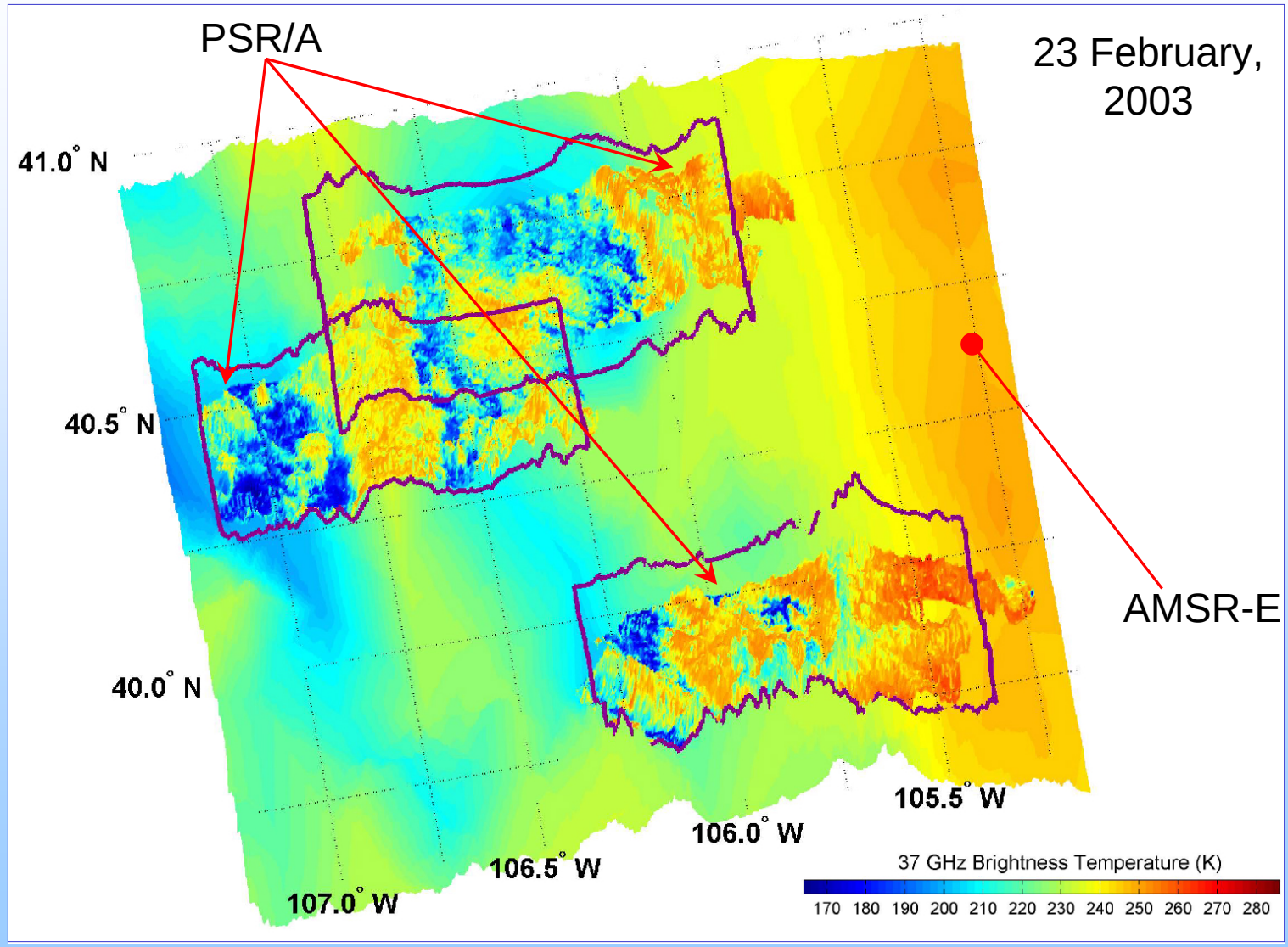
AMSR-E to PSR/A T_B Intercomparison

- 18.7 GHz H-pol -



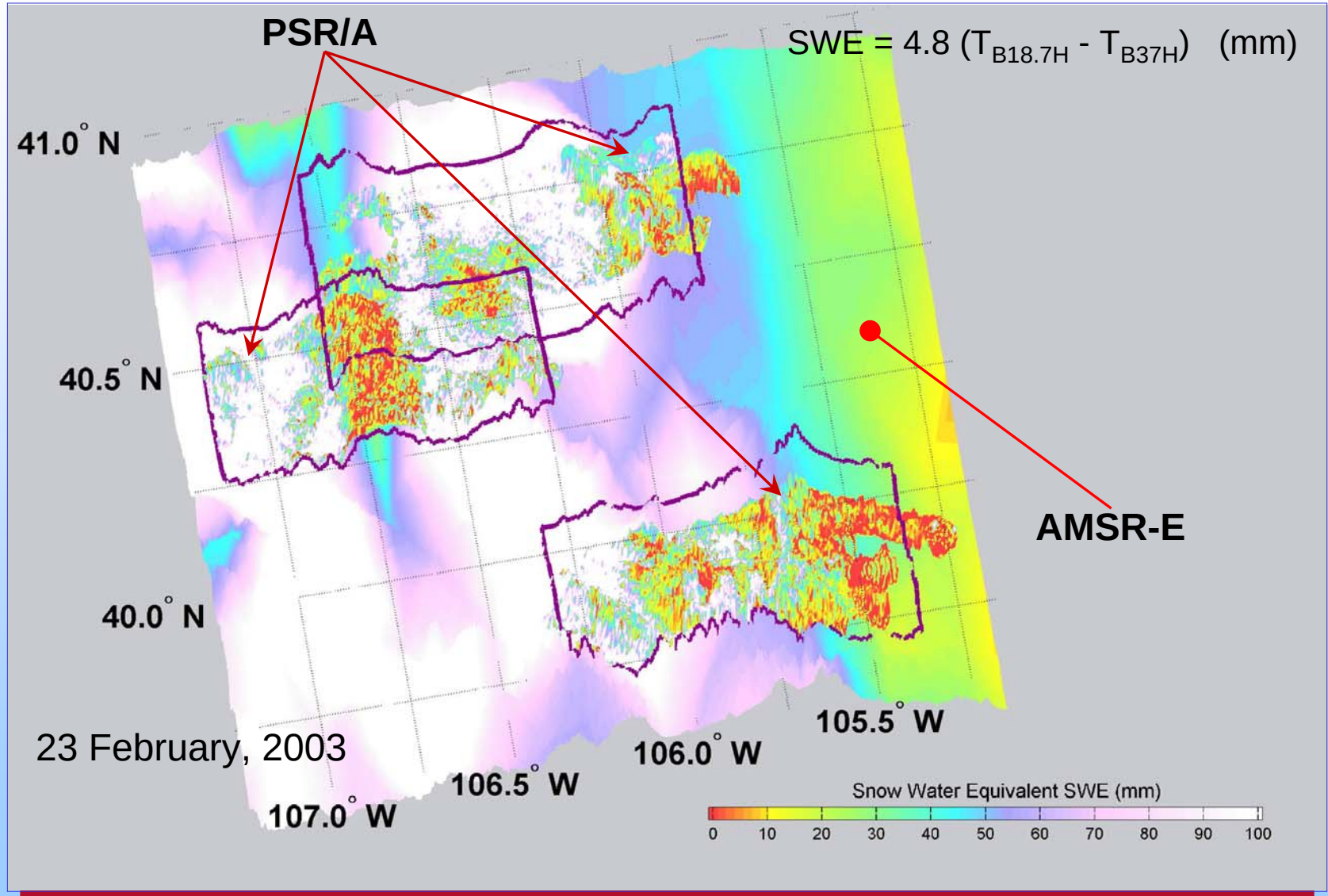
AMSR-E to PSR/A T_B Intercomparison

- 37.0 GHz H-pol -



AMSR-E to PSR/A Intercomparison

- SWE Product -



Preliminary comparisons of the grain size corrected PSR SWE estimates for North Park

MSA data show that: mean snow density = 0.18 g cm^{-3}
average snow grain radius = 0.57 mm

SWE AMSR-E algorithm with these parameters becomes:

$$\mathbf{SWE = 1.2*(T_{B18.7H} - T_{B37H})/(1-0.2ff)}$$

where forest factor, ff = 0.0.

Estimates for:

(2/22/03) PSR area averaged SWE = 20.1 mm

(2/21-22/03) Field measurements SWE_{mean} = 23.5 mm

(2/21/03) NOAA/NOHRSC airborne gamma survey SWE = 45.7 cm (un-corrected)

(2/21/03) AMSR–E area averaged SWE (corrected) = 37 mm

PSR Snow Emissivity Computing Method

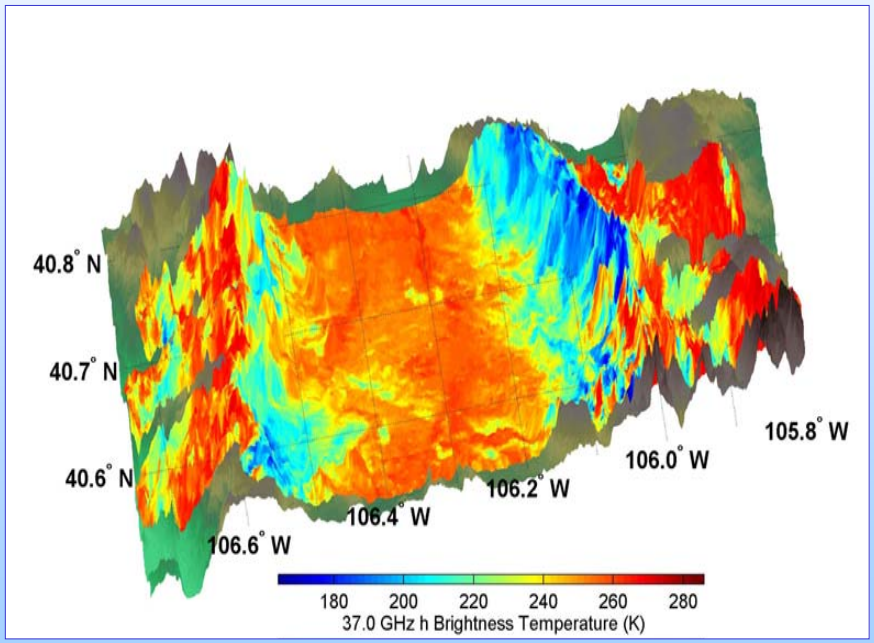
Maps of the microwave surface emissivity for the clear air cases during CLPX02 were computed from the PSR-measured T_B by removing atmospheric contribution to the observed T_B in the following way:

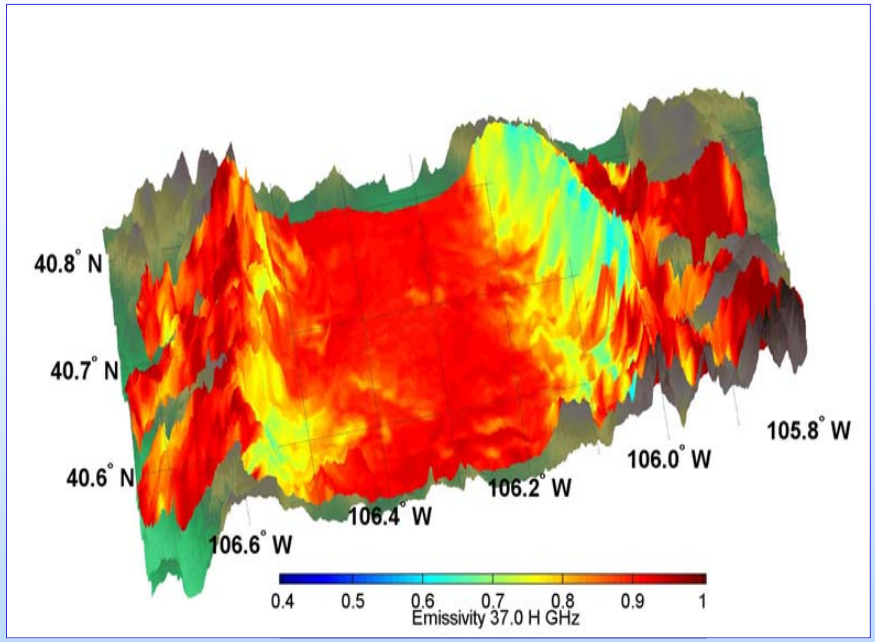
- Use Denver NWS radiosonde temperature and water vapor profiles modified within the surface boundary layer with the measurements from a surface micrometeorological tower located at North Park.
- Use PSR-measured 10μm IR T_B measurements to represent surface temperatures.
- Use Microwave Radiative Transfer (MRT) model with corrections that included the angle of incidence of specular rays consistent with the local terrain slope.

PSR Snow Emissivity Example

- North Park February 23, 2002 CLPX02 -

37.0 GHz Brightness Temperature

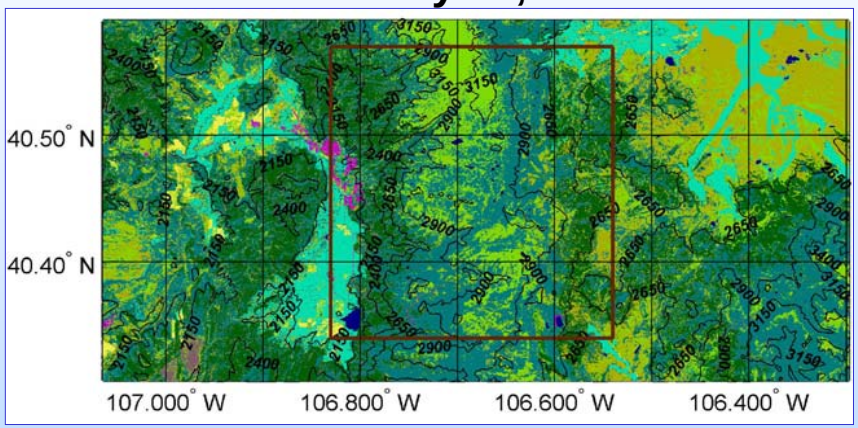




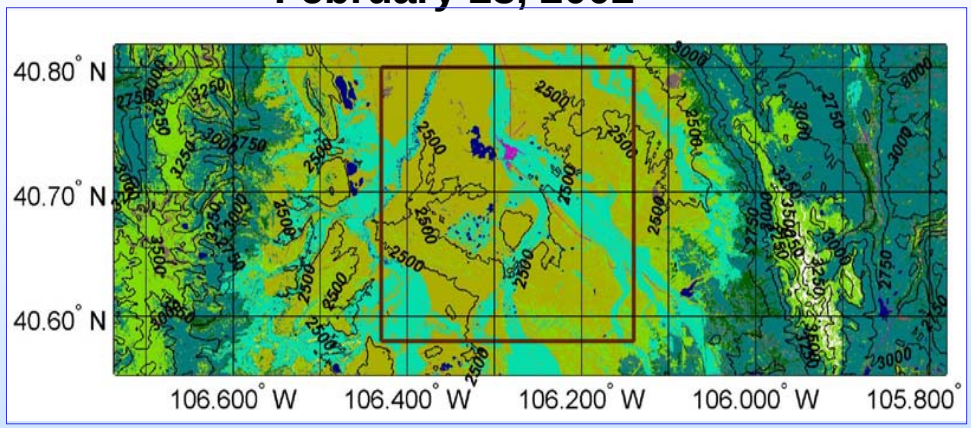
37.0 GHz Emissivity

USGS 30 m resolution Land Cover data

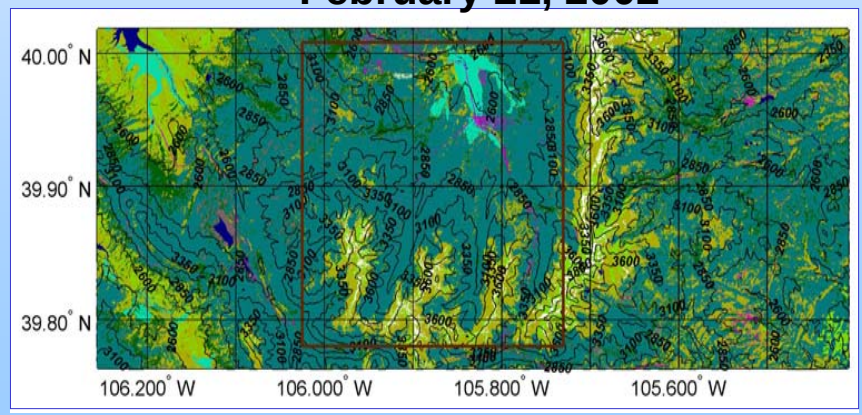
Rabbit Ears PSR data coverage
February 19, 2002



North Park PSR data coverage
February 23, 2002

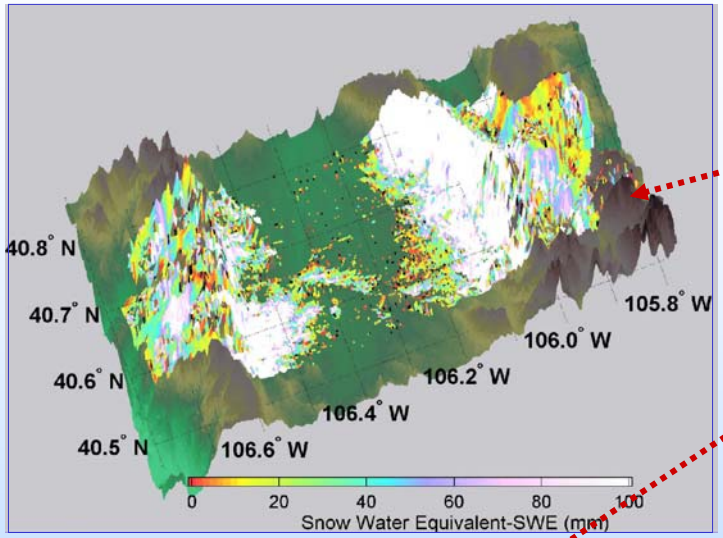


Fraser PSR data coverage
February 21, 2002



Normal Components Analysis for CLPX02

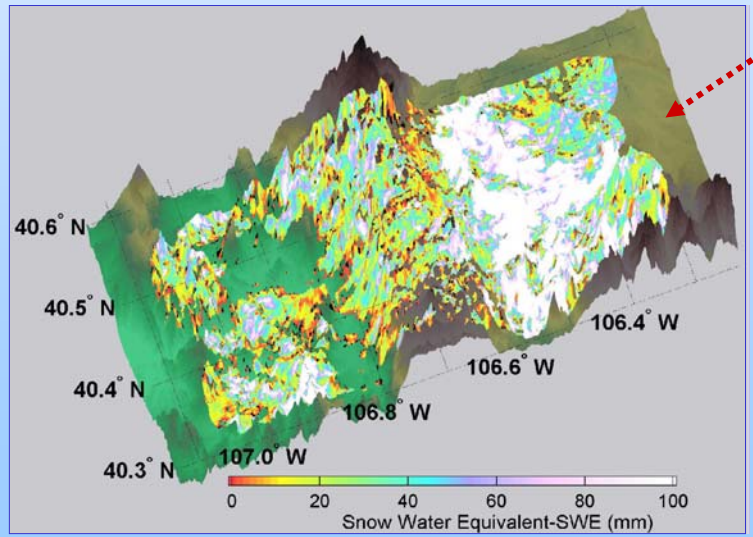
- SWE used for Snow/No Snow Information -

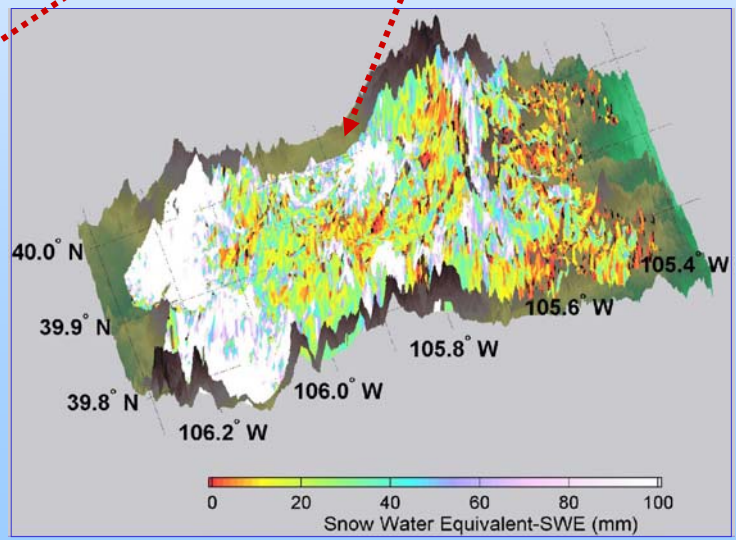


North Park

Rabbit Ears

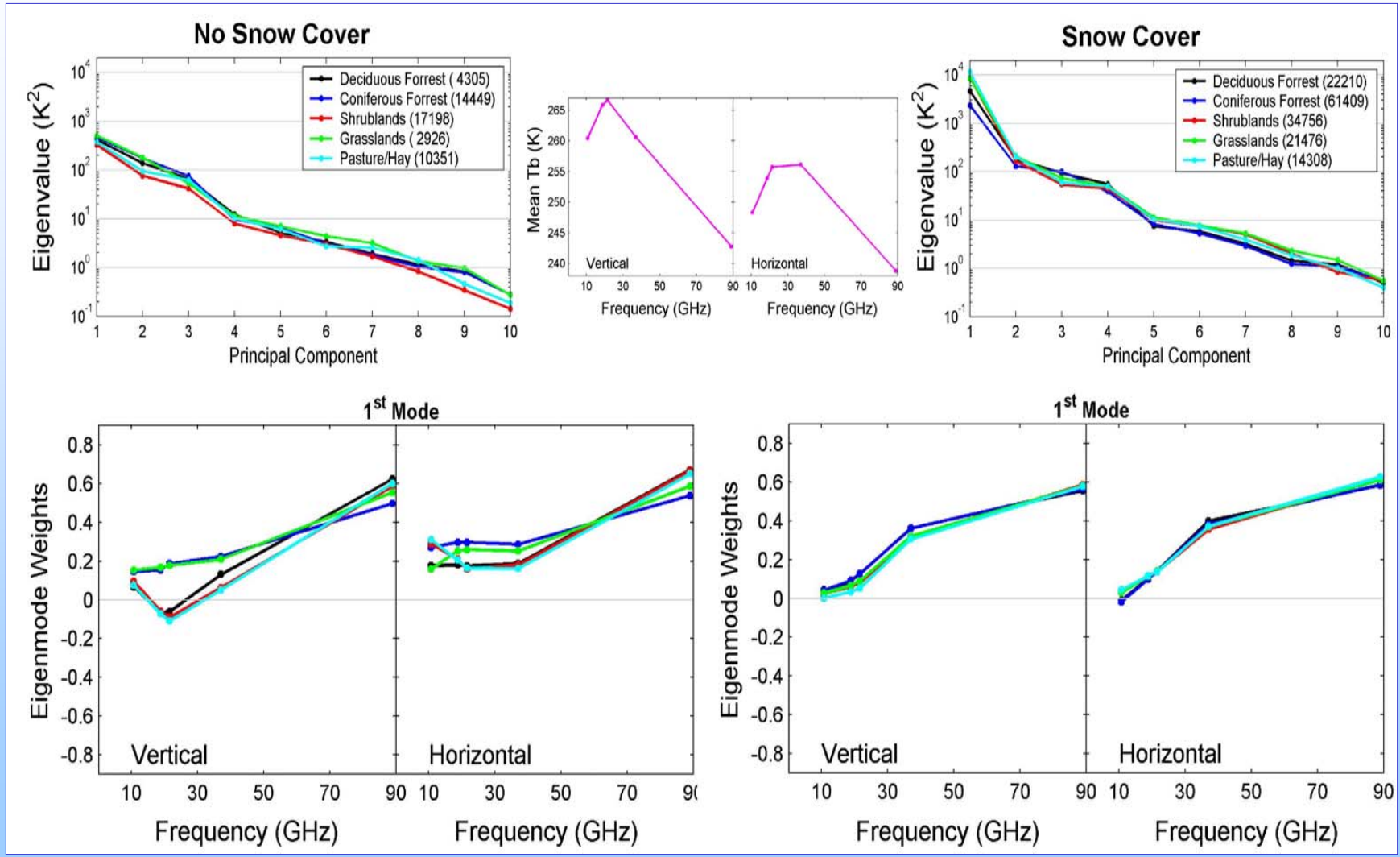
Fraser





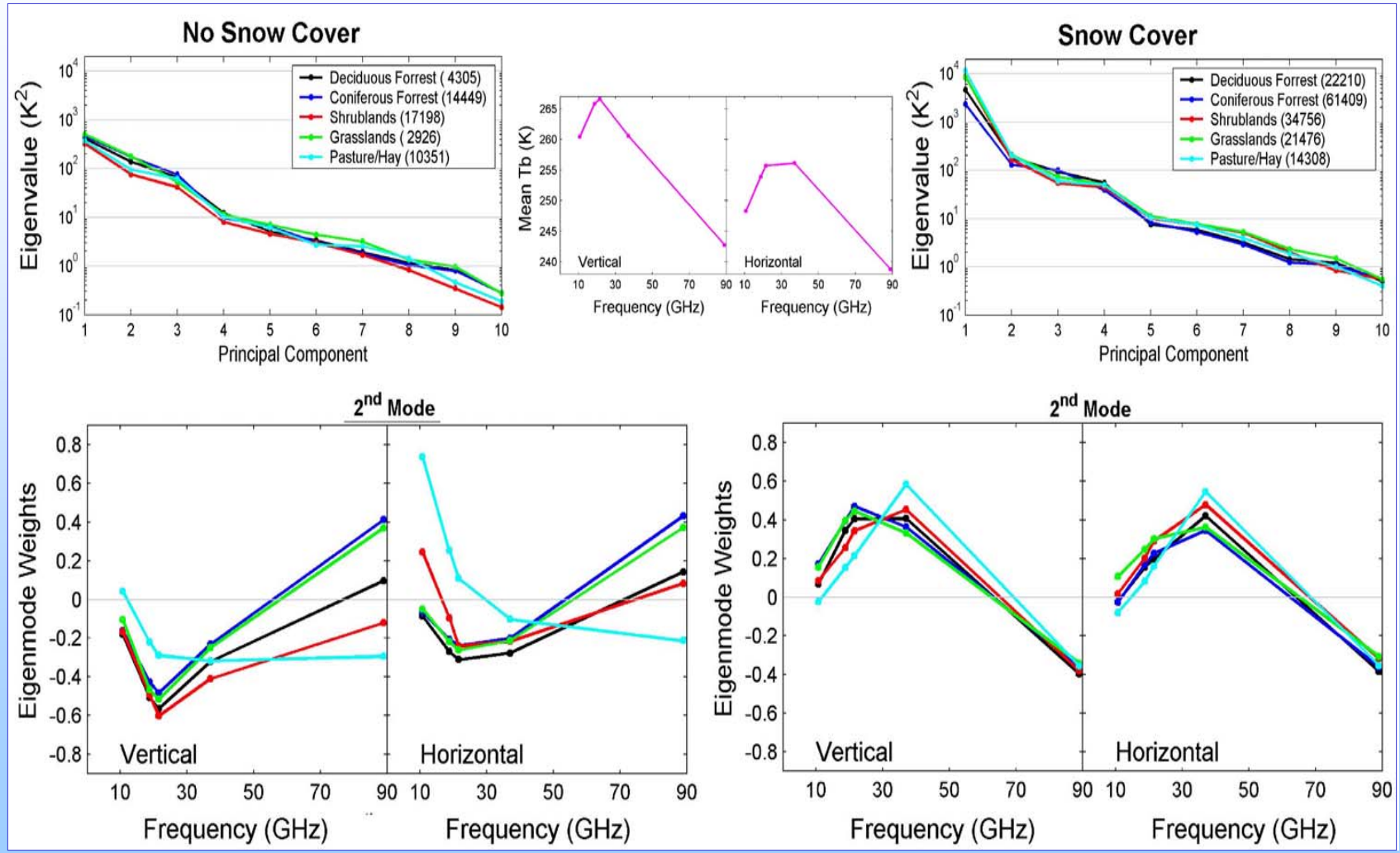
Normal Components Analysis: 1st Mode

- CLPX02 T_B, USGS Land Cover (NP, RE, FM) -



Normal Components Analysis: 2nd Mode

- CLPX02 T_B, USGS Land Cover (NP, RE, FM) -



Conclusions

- The first high-resolution observations and retrievals of snow pack properties using the PSR multi-channel conically-scanned airborne microwave radiometer during CLPX have been presented.

- The results show promise for improved observation, understanding, and prediction of snow properties.

- PSR's ability to characterize the spatial variability of SWE at sub-kilometer spatial scale is important for effective water resource management.

Future Work

- Use the entire CLPX data set that consists of 21 flights to study relationships between land cover and PSR brightness temperature observations in all channels to establish new relationships and develop new algorithms.

- Tailor new algorithms to use information from all channels since satellite algorithms for anything but 18 & 37 GHz channels have not been studied in great depth.